- θ is not constant and change in [0.1 1.2]
- Maximum iteration is set on 300

Table(1) : Pesudo code of proposed method

```
Step 1: set the maximum iteration of each ICA to 300
Step 2: set the number of countries to 80
Step 3: set the number of imperialists to 8
Step 4: start three ICAs simultaneously
Step 5: capture the first two best results of ICAs and set it as starting point of 4th ICA
Step 6: Start 4th ICA
Step 7: return final results
```

III. Simulation and results

In order to test our work, we use two different benchmark functions (Griewank and Rastring both with 10 parameter to be optimized) [5]. Also we use ICA with 1500 iterations, GA with 1500 iterations and SA with starting temperature of 2000 as other optimization techniques. We run algorithms for each function for 100 times. The results are illustrated in Table (2) and Table (3).

Table(2) : Grienwank function results

	Min answer (mean)	SD	Time (seconds)	Global min
ICA	0.0288	0.0329	234.98	0
GA	2.751	2.541	564	0
SA	4.293	3.783	634	0
PICA	0.0021	0.0435	77.16	0

Table(3) : Grienwank function results

	Min answer (mean)	SD	Time	Global min
ICA	2.21	3.26	316	0
GA	9.37	5.4	652	0
SA	12.67	4.7	721	0
PICA	0.029	0.159	72.4	0

The results shows that our proposed method beside the fastest converge to the global minimum, has great performance in subject of the min answer and standard division (SD) of answers which is make the method a precise, fast and reliable method for global optimization tasks. In this context, the reliable method is defined as method which can search the whole search space and find the best local optimum with low range of differentiation. Hence, we can see, our proposed method show noticeable results in compression with basic optimization methods.

IV conclusion

In this work we demonstrate an architecture for optimization based on imperialist competitive algorithm. We show that our proposed method can work on complex problems properly. PICA also shows that it is better than most of the individual evolutionary methods in subject of converge speed, accuracy and reliability. In future, this family of methods can easily combine with other evolutionary algorithms in order to cover their weaknesses. Also, the introduced method can be applied in real word applications to measure its real performance.

Furthermore, we suggest to researchers to improve the basic methods using new random paradigms in order to add more diversity then using evolutionary methods in new architectures such as the architecture we propose.

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УДК 681.2

STABILITY CONDITIONS IN THE QUASI-STATIC MODE OF A DIFFERENTIAL-CAPACITIVE INSTRUMENT

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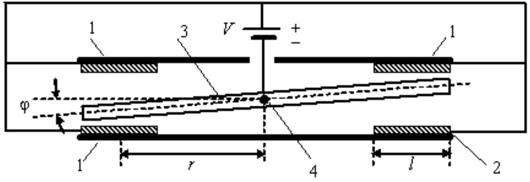
Capacitive sensing has advantages compared to other types of sensors. Its attractive properties are: little power consumption, very low sensitivity to temperature, and less complex shielding stray electric fields than shielding inductive sensors from magnetic disturbances [1]. The capacitive sensors have low noise floor, low fabrication cost, low cross-coupling sensitivity. It has also compatibility with Very Large-Scale Integration (VLSI) technology scaling, all of which make it commercially implementable in recent years [2, 3]. Capacitive sensors have different usages in MEMS and micro sensors [4-6].

There are different techniques for making capacitive sensors and also different interface circuits that supply sensors with energy. Sensors with one variable capacitor are nonlinear to an output signal in most cases. By employing the structure of differential capacitors instead of one variable capacitor it is possible to have simpler circuit and also to reduce the nonlinear effects of sensors [7-9]. Additional method may be used to enhance the linearity of a differential capacitive sensor [10].

It is difficult to keep these influences and parasitic capacitors under control. Also, the electrical excitation circuit adds additional floor noises in output signals of the sensor.

Electrostatic differential capacitive force and torque sensor. The electro-mechanical model of a simple and sensitive resonant electrostatic differential capacitive force and torque sensor represent in figure 1 where AC generator is substituted for an electrostatic generator. Many features of this actuator have been investigated before [11, 12], particularly, the nonlinear features, stability and instability.



1 – fixed non-conductive plate, 2 – conductive substrate, 3 –conductive plate, 4 – elastic suspender.

Figure 1 – The sensor's model

The moveable plate 3, e.g. sensitive plate (SP) performs angular movements under the action of external torque $M(t)$ of force which have to be measured. This torque is considered as harmonic with frequency $\omega=2\pi f$, so that

$$M(t)=M_0\cdot\cos(\omega t). \qquad (1)$$

The sense of M_0 has to be defined in a concrete problem. For example, in a linear accelerometer $M_0 = mas$, where m – is mass of SP, a is a linear acceleration, and s – is a static unbalance. In an angular accelerometer $M_0 = I_z\varepsilon$, where I_z – moment of inertia of a SP relative to a rotation axis z, ε – is an angular acceleration.

Physical model of the sensor. The sensor's computational model is shown fig. 2. The angular displacements of a SP in this model are represented as the translations of an intermediate plate. This is possible because the rotations of SP are very small. In this model it is supposed that all details are in vacuum, squeezed-film damping is absent, electric capacitors are ideal, fringing effects are ignored, and spring stiffness k is constant. The damper in figure 2 describes the mechanical energy dissipation in the sensor.

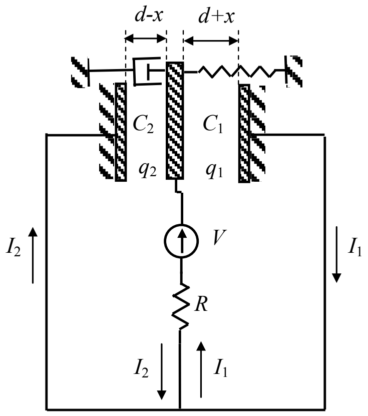


Figure 2 – The electro-mechanical model of the sensor under study

The voltage V in figure 2 is a voltage source. Capacitance for ideal capacitors with flat plates are expressed in Eq.(2).

$$C_1=\frac{C_{01}}{1+x/d},\ C_2=\frac{C_{02}}{1-x/d}. \qquad (2)$$

Because rotations φ of a SP are small, a displacement $x\approx\varphi\cdot r << d$ (see figure 2), hence

$$C_1=\frac{C_{01}}{1+\varphi/\varphi_m},\ C_2=\frac{C_{02}}{1-\varphi/\varphi_m}, \qquad (3)$$

where $\varphi_m\approx\frac{d}{r}$.

It is obvious that the initial capacitances C_{01} and C_{02} are different in real capacitive sensors. Let us assume a relationship as:

$$C_{02}=(1+\gamma)C_{01}. \qquad (4)$$

The equation of oscillations of SP is given by Eqs. (5) and (6):

$$I_z\ddot{\varphi}+D\dot{\varphi}+k\varphi=M(t)-M_{el}, \qquad (5)$$

$$M_{el}=2F_{el}r\cos\varphi, \qquad (6)$$

where $F_{el}=F_{el2}-F_{el1}$, and F_{el1} – is the force acting on SP in capacitor C_1 [2, 23]:

$$F_{el1}=\frac{1}{2}\frac{q_1^2}{\varepsilon_0 S}, \qquad (7)$$

where ε_0 – electric constant, q_1 – electric charge in capacitor C_1, S – area of one of substrates 2 (figure 1), F_{el2} – is the force acting on a SP in capacitor C_2:

$$F_{el2}=\frac{1}{2}\frac{q_2^2}{\varepsilon_0 S}. \qquad (8)$$

The factor 2 appearing in Eq. (6) is due to two pairs of differential capacitors in the sensor (fig.1). Eq. (6) and below it is supposed that $\cos\varphi\approx 1$.

From Eqs. (6) and (8), the following is obtained.

$$M_{el}=\frac{q_2^2-q_1^2}{\varepsilon_0 S}r. \qquad (9)$$

Eq.(5) can be rewritten, if to take into account equations (6) – (9), as:

$$I_z\ddot{\varphi}+D\dot{\varphi}+\left(k\varphi-\frac{q_2^2-q_1^2}{\varepsilon_0 S}r\right)=M_0\cos(\omega t). \quad (10)$$

The analysis of a quasi-static stability of the sensor. The energy dissipation and external forces are assumed to be absent at this stage of the investigation. If the resistor R is too small to affect SP movement and currents I_1 and I_2, the free movement equation of SP follows Eq. (11):

$$I_z\ddot{\varphi}+\left(k\varphi-\frac{q_2^2-q_1^2}{\varepsilon_0 S}r\right)=0. \quad (11)$$

It can be seen from figure 3 and from Kirchhoff's law that,

$$\frac{q_1}{C_1}+\frac{q_2}{C_2}=0, \quad q_1=C_1V. \quad (12)$$

The capacitors C_1 and C_2 are given by Eq.(3). In this case Eq. (11) may be defined as

$$I_z\ddot{\psi}+M(\psi)=0, \quad (13)$$

where

$$M(\psi)=k\left[\psi-B\frac{\gamma_1^2(\psi+1)^2-(\psi-1)^2}{\left(1-\psi^2\right)^2}\right] \quad (14)$$

is a resulting moment acting on SP in electric field,

$$B=\frac{4C_{01}V^2}{k\varphi_m^2},\ \psi=\frac{\varphi}{\varphi_m},\ \gamma_1=\gamma+1. \quad (15)$$

If $\psi<<1$, it will be shown lower the parameter B may be defined as the following relationship:

$$B=1-\frac{\Omega_0^2}{\omega_0^2}, \quad (16)$$

where $\omega_0=\sqrt{\frac{k}{I_z}}$ is SP resonance frequency when electrostatic field is switch off; and Ω_0 is SP resonance frequency when electrostatic field is switched on (see Eq. (34) lower).

The SP oscillations are stable if a derivative $\frac{dM(\psi)}{d\psi}\le 0$. The derivative is given in Eq. (17):

$$\frac{dM(\psi)}{k\,d\psi}=\frac{2\psi^6-6\psi^4+B\left(\gamma_1^2-1\right)\psi^3}{2\left(1-\psi^2\right)^3}+\frac{3\left(B\gamma_1^2+B+2\right)\psi^2+3B\left(\gamma_1^2-1\right)+B\left(\gamma_1^2+1\right)-2}{2\left(1-\psi^2\right)^3} \quad (17)$$

and is shown in Fig. 4. The values $\gamma<<1$ and B is close to 1 are most interesting. Then values $\psi<<1$, and the first two members in the numerator might be omit. The one has

$$\frac{dM(\psi)}{k\,d\psi}\approx\frac{B\left(\gamma_1^2-1\right)\psi^3+3\left(B\gamma_1^2+B+2\right)\psi^2}{2\left(1-\psi^2\right)^3}+\frac{3B\left(\gamma_1^2-1\right)+B\left(\gamma_1^2+1\right)-2}{2\left(1-\psi^2\right)^3}. \quad (18)$$

The fig. 3 shows this derivative also.

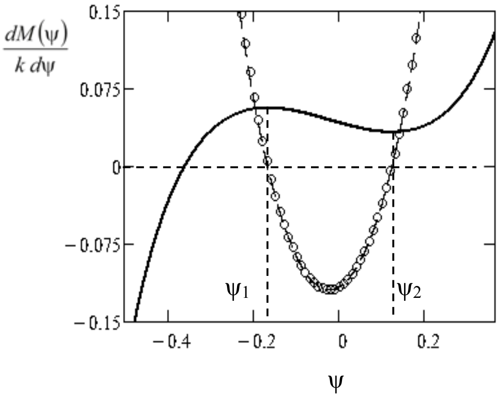


Figure 3 – The dependences of moment $\frac{M(\psi)}{k\varphi_m}$ and its derivatives on a parameter ψ, if B =0.8 and γ=0.1. The continuous line corresponds to Eq. (14); the dashed line corresponds to Eq. (17); the dotted line corresponds to Eq. (18).

The angles $\psi_1$and ψ_2 can are calculated from an equality $\frac{dM(\psi)}{d\psi}=0$. It follows from Eq. (18)

$$\psi_1=-\frac{\sqrt{3}\sqrt{16-14B^2\gamma_1^2-B^2\left(\gamma_1^4+1\right)}+3B\left(\gamma_1^2-1\right)}{6\left(B\gamma_1^2+B+2\right)}, \quad (19)$$

$$\psi_2=\frac{\sqrt{3}\sqrt{16-14B^2\gamma_1^2-B^2\left(\gamma_1^4+1\right)}-3B\left(\gamma_1^2-1\right)}{6\left(B\gamma_1^2+B+2\right)}. \quad (20)$$

The expression which is under square roots in Eqs. (19) and (20) has to be positive. It follows from this that $B\le B_{max}$, where

$$B_{\max}=\frac{4}{\sqrt{1+14\gamma_1^2+\gamma_1^4}}.$$

If γ=1 (i.e. γ_1=2), error of this equality is about 0.003 in comparison with exact one, and it quickly decreases when γ is decreasing.

The SP irrepressibly rushes to one of static plates if ψ is out of interval ψ_1-ψ_2. This phenomenon is called pull-in (or "snap-down") in actuators [11].

The main conclusion which issues from formulas (16), (19) - (21) is that the parameter γ limits a parameter B_{max} , i.e. limits minimum of a frequency Ω_0 which is 0.3 ω_0. The SP stable oscillations angle interval becomes very narrow if $B \to B_{max}$. These constitute disadvantages for this sensor as fabricating an ideal symmetric sensor is rather complicated. But an asymmetry in the sensor can be compensated as discussed next.

Conclusion. The most challenging issue in designing instruments with high sensitivity measurement of inertial and gravitational forces constitutes a dilemma in securing robustness and sensitivity of the elastic suspension of the mobile element. In the usual approach, the robustness can be sacrificed to the benefit of the sensitivity, and as result the suspensions are insecure. This paper has considered differential-capacitive electrostatic sensors where robustness has been considered. This sensor is intended to measure harmonic signals, such as linear and angular accelerations and second derivatives of gravity potentials. The sensor's construction combines a dual function of an electrostatic capacitive differential sensor and electrostatic capacitive actuator without any additional elements. The actuator permits to decrease the resonance frequency of the sensor and by-turn this actuator permits to use a harder elastic suspension for sensing plate.

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РАЗРАБОТКА ТЕОРЕТИЧЕСКИХ И МЕТОДИЧЕСКИХ ОСНОВ УПРАВЛЕНИЯ АВАРИЙНЫМИ СБРОСАМИ В ТЕХНОЛОГИЧЕСКОМ ПРОЦЕССЕ ОЧИСТКИ СТОЧНЫХ ВОД В КОНТЕКСТЕ СОЦИО-ЭКОЛОГО-ЭКОНОМИЧЕСКОЙ СИСТЕМЫ КРУПНОГО ПРЕДПРИЯТИЯ

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Трудно переоценить роль воды в нашей жизни. К сожалению, в реальности вода в большинстве случаев загрязнена множеством соединений, концентрации которых часто превышают нормы. Контроль качества воды затрагивает очень многие стороны жизни человеческого общества. В настоящее время из-за обострившихся угроз загрязнения воды контроль ее качества становится проблемой социальной, политической, медицинской, географической, а также инженерной и экономической.

Существенный вклад в загрязнение воды вносят сточные воды промышленных предприятий. Постоянно возрастающие объёмы сточных вод, увеличивающееся количество видов и степени загрязнений существенно осложняют решение вопросов минимизации экологических рисков и управления экологической обстановкой в крупных городах [1].

Вопросы совершенствования структуры системы управления сточными водами, ее функционирование в городской среде в условиях наличия крупных предприятий, рационализация межотраслевых взаимодействий в указанной сфере требуют дальнейшего изучения и обобщения. Первостепенное значение имеет разработка теоретических и методических основ управления сточными водами с учетом социально-экологического и экономического потенциала крупных предприятий [2].

Существующие методы анализа сточных вод, как правило, требуют применения сложной аппаратуры и значительного времени для проведения анализа, что не всегда возможно в производственных условиях. Это не позволяет в режиме